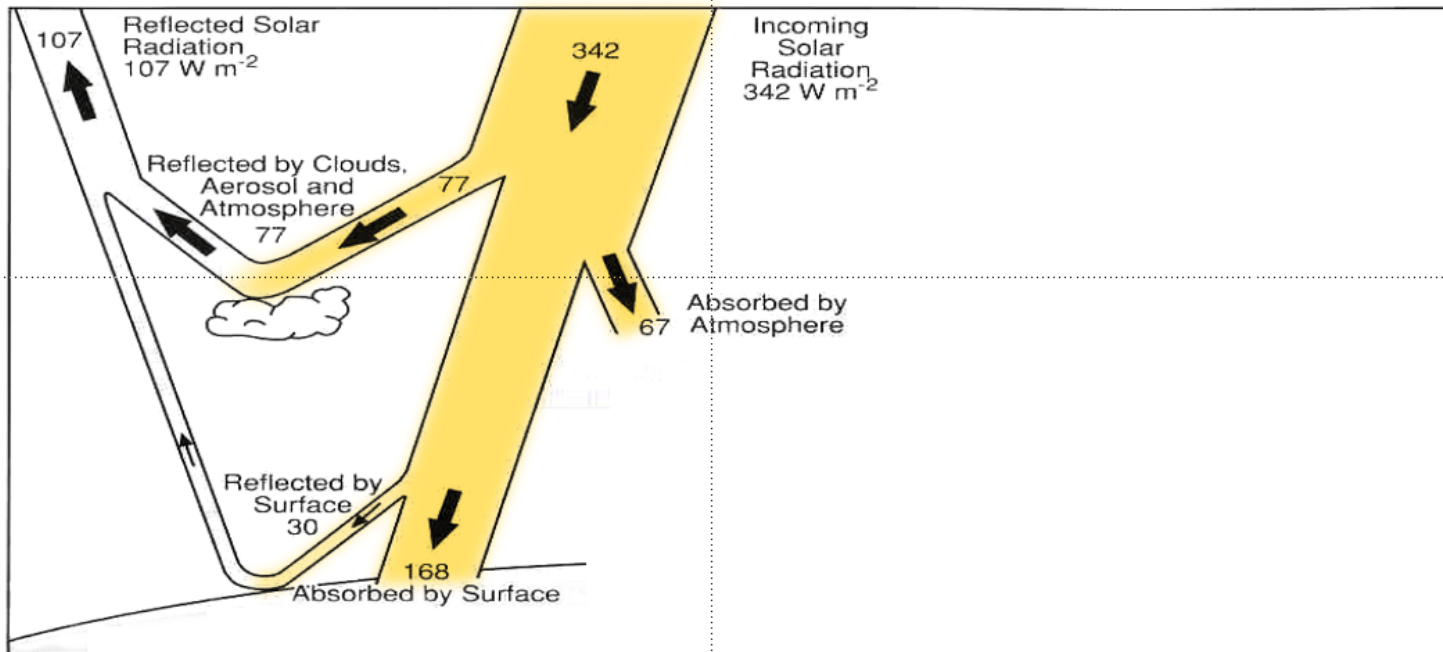


GLOBAL CLIMATE CHANGE

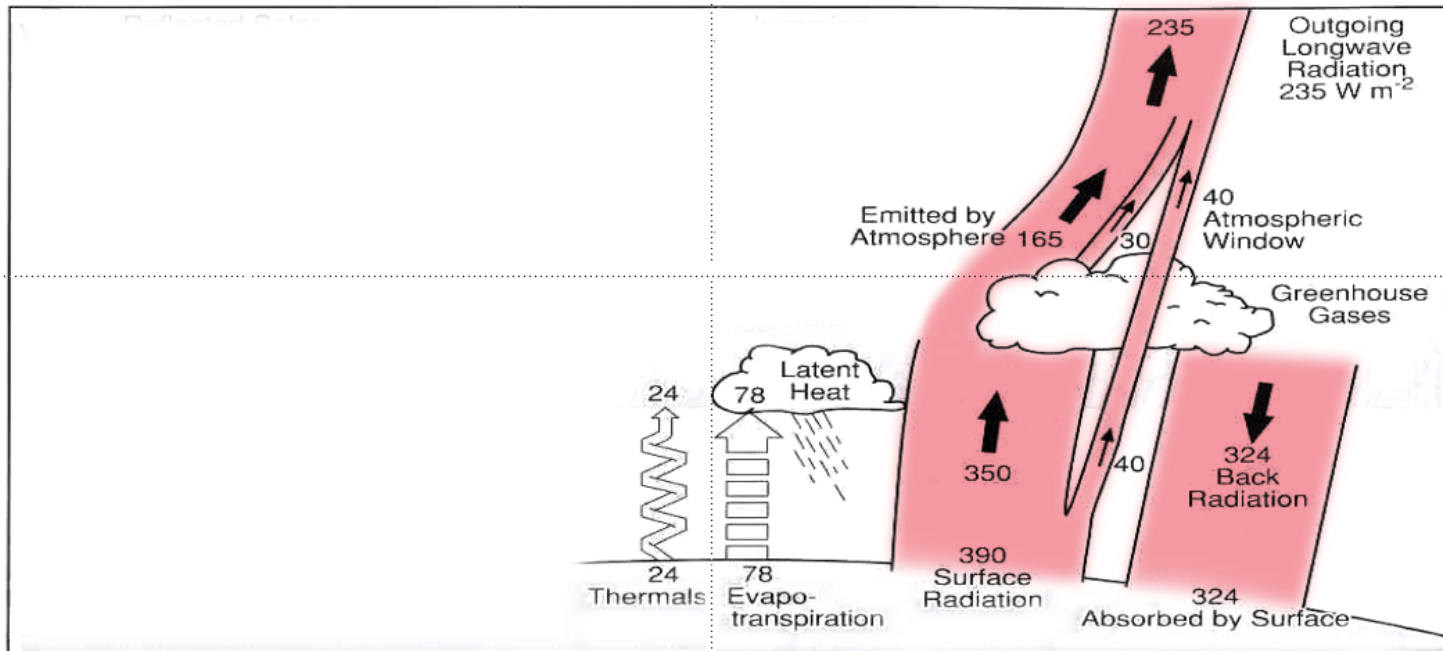


John H. Seinfeld
California Institute of Technology

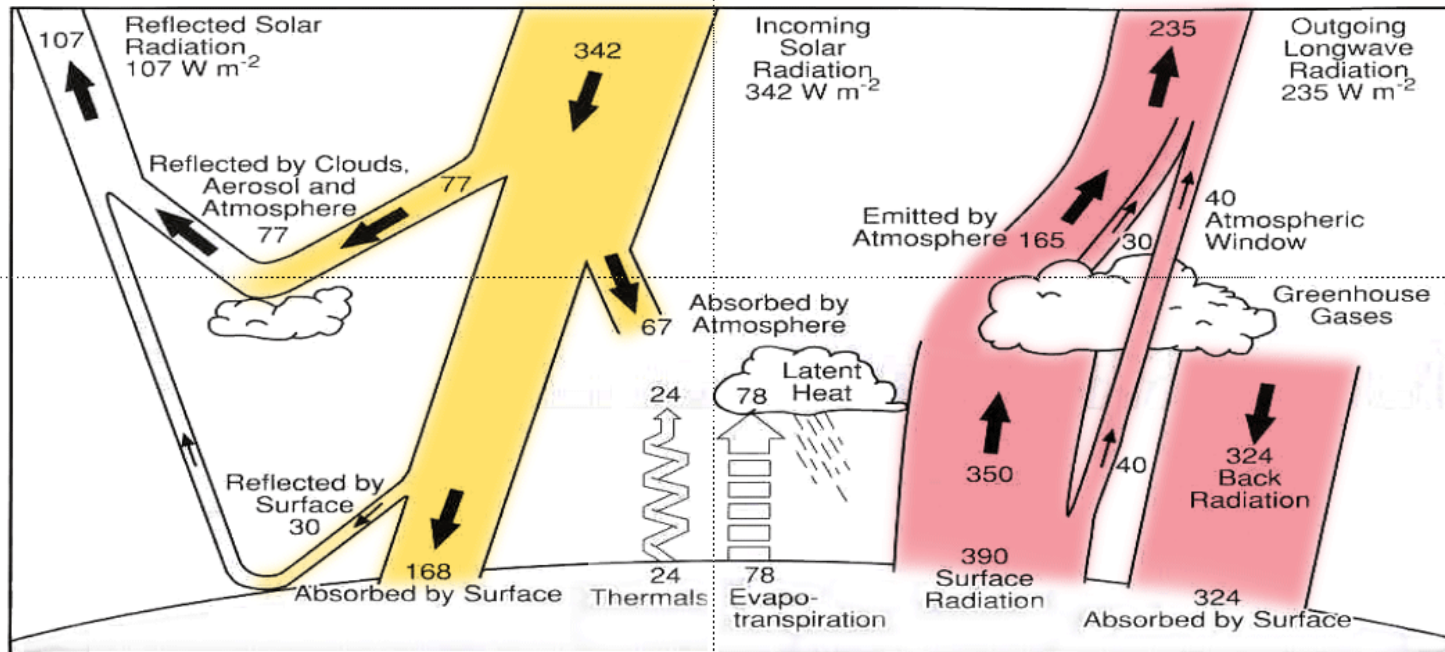
The Earth's Energy Balance

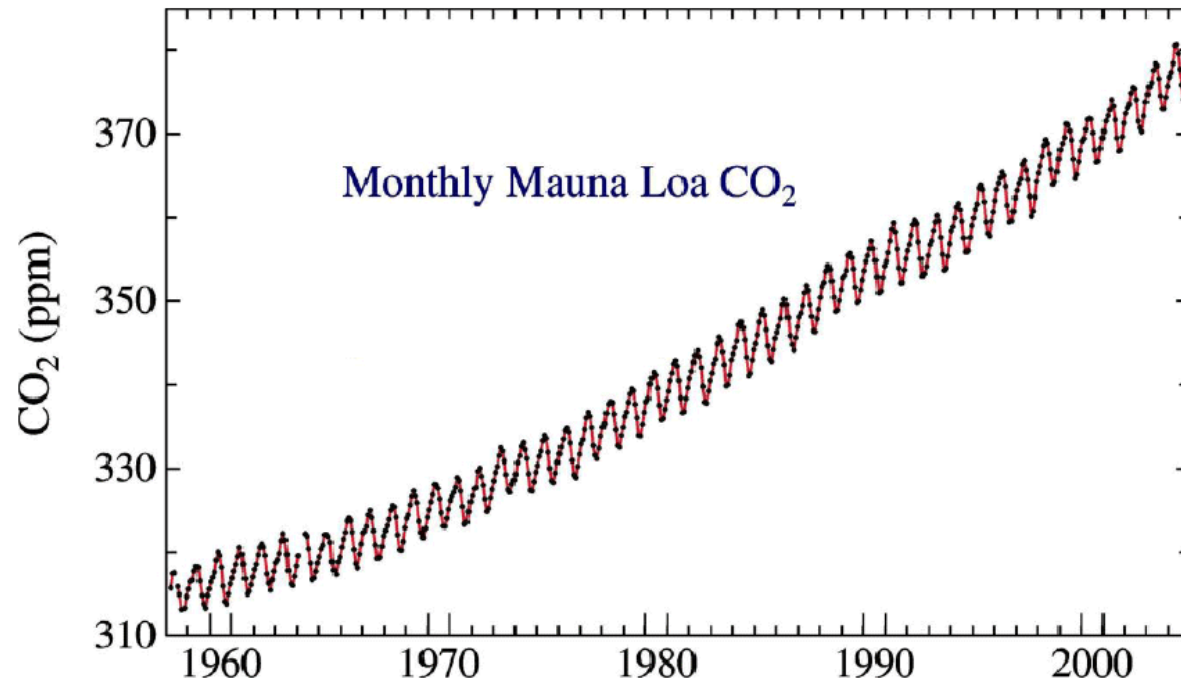


The Earth's Energy Balance



The Earth's Energy Balance





Atmospheric CO₂ measured at Mauna Loa, Hawaii.

Source: NOAA Climate Monitoring and Diagnostic Laboratory

Carbon fluxes are measured in gigatons (Gt)
(giga = 1 billion)

1 metric ton = 1000 kg

1 Gt = 1 billion (10^9) metric tons

How large is the human release of carbon?

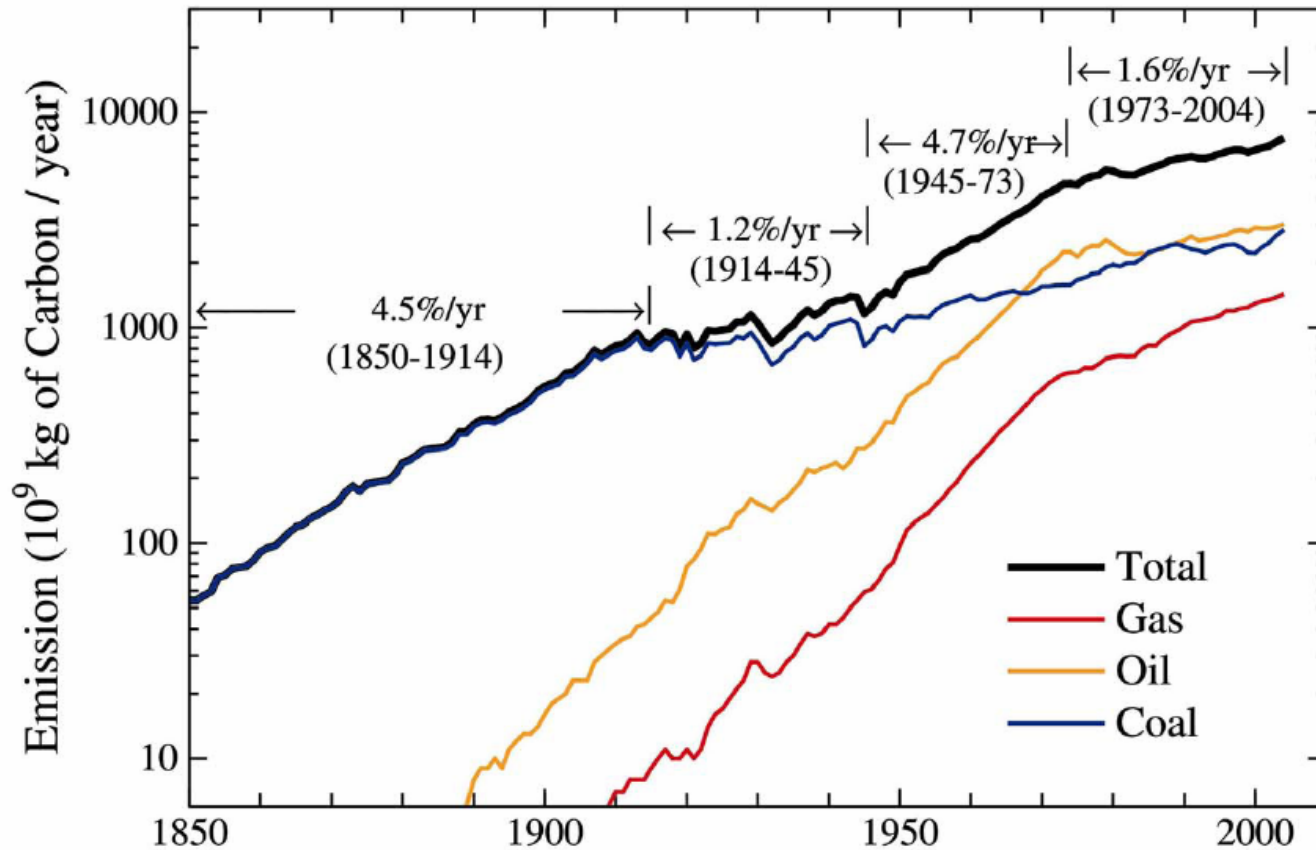
Human activities release about 7 Gt = 7×10^9 metric tons of carbon per year



One 2007 Toyota Camry Hybrid weighs 3637 pounds = 1.65 metric tons

7 Gt Carbon = 4,240,000,000 Camrys

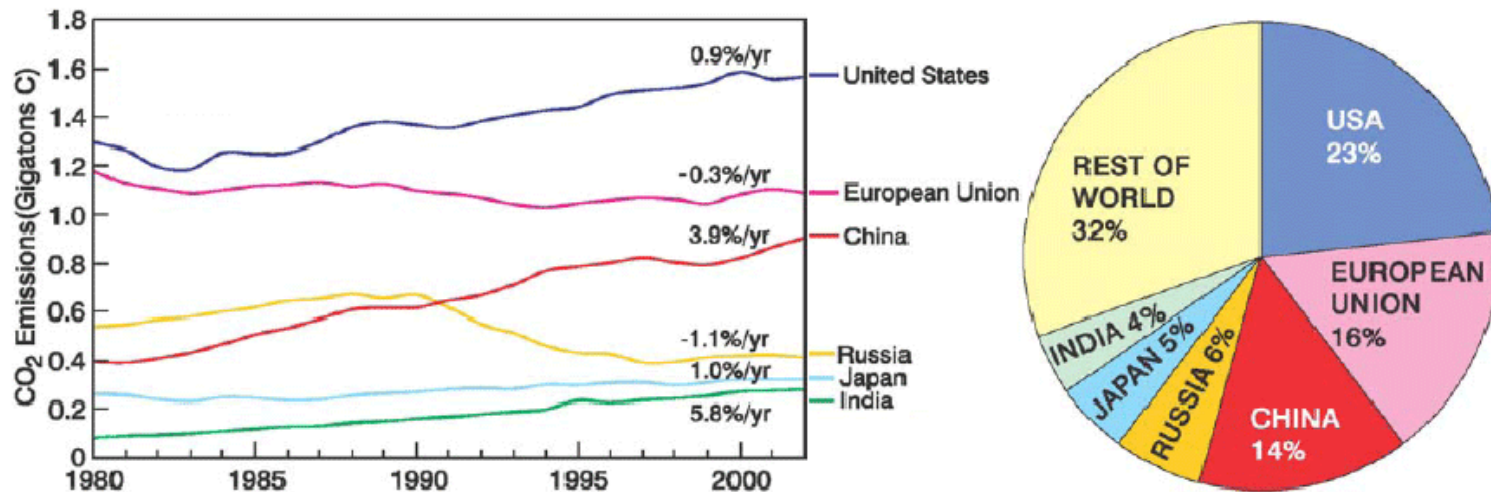
Global Fossil-Fuel CO₂ Annual Emissions



Fossil fuel CO₂ emissions based on data of Marland and Boden (DOE, Oak Ridge) and British Petroleum.

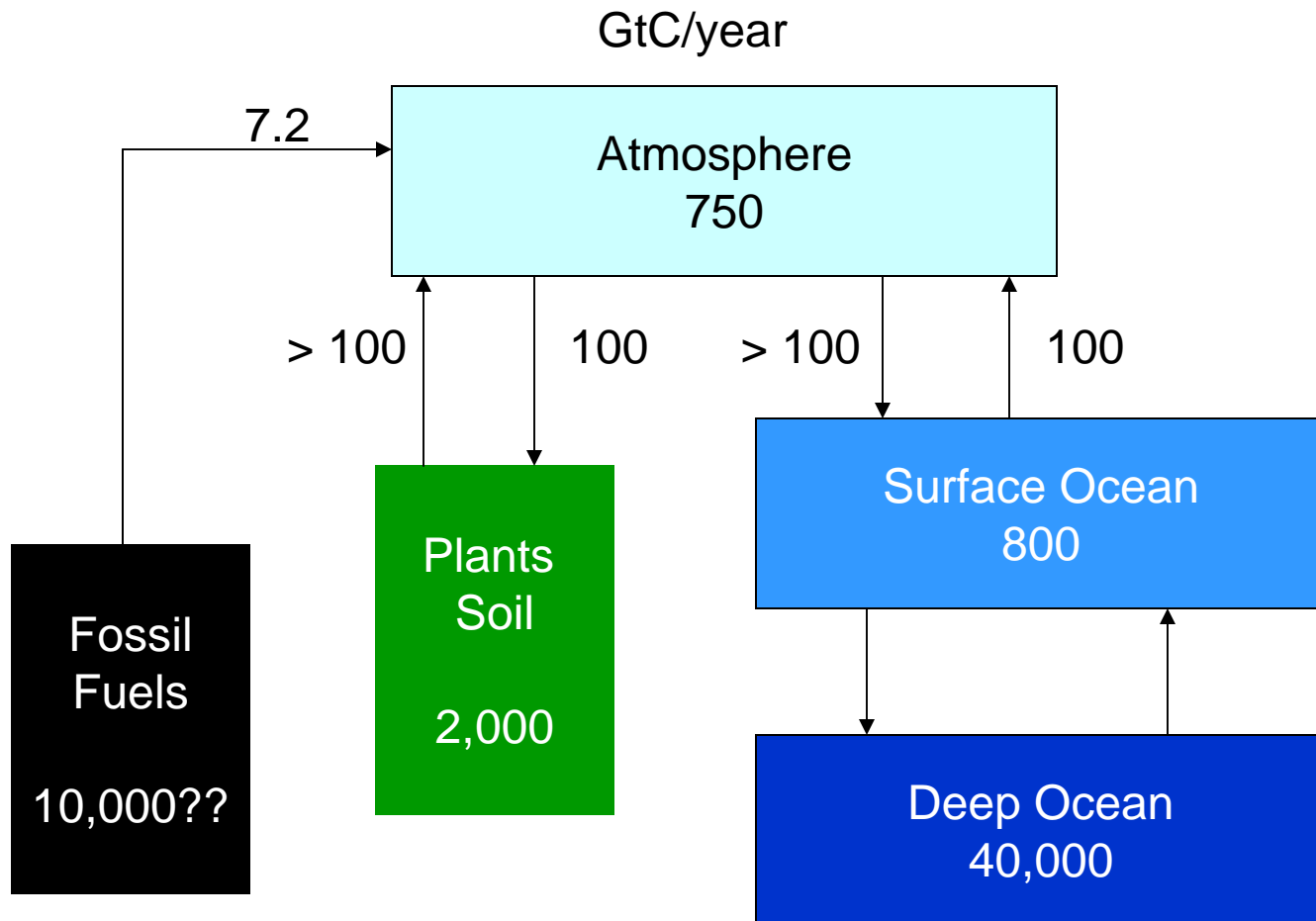
Source: Hansen and Sato, *PNAS*, **98**, 14778, 2001.

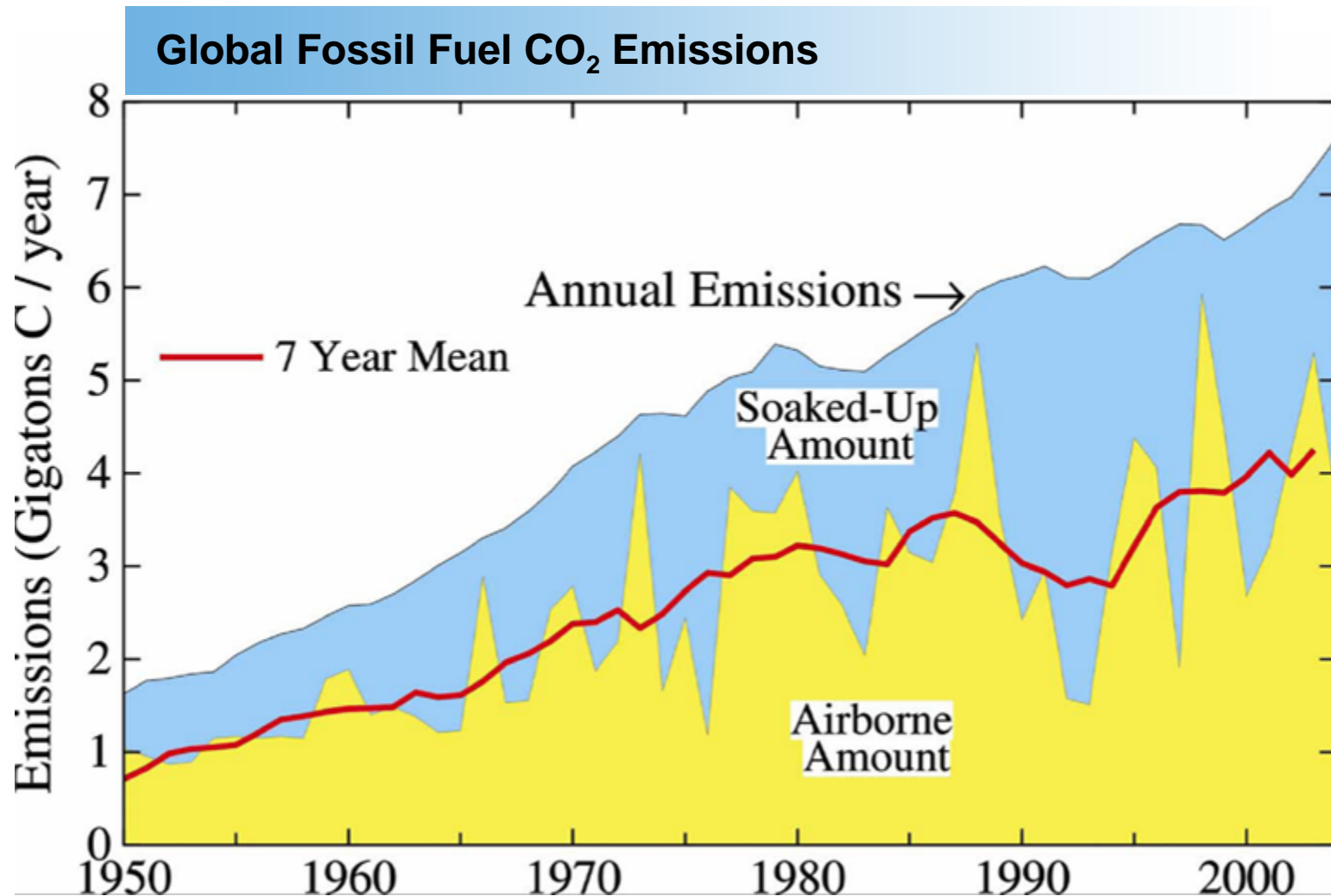
World CO₂ Emissions (2002)



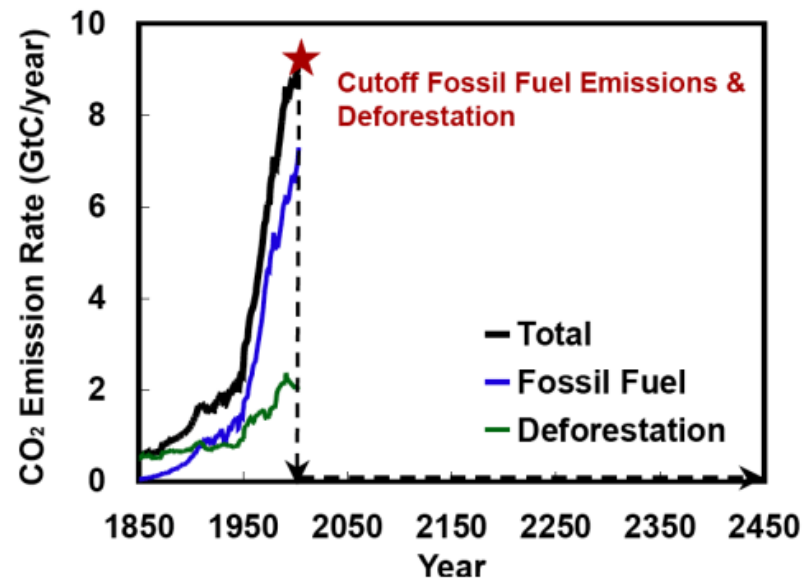
Source: Energy Information Administration, U.S. Department of Energy

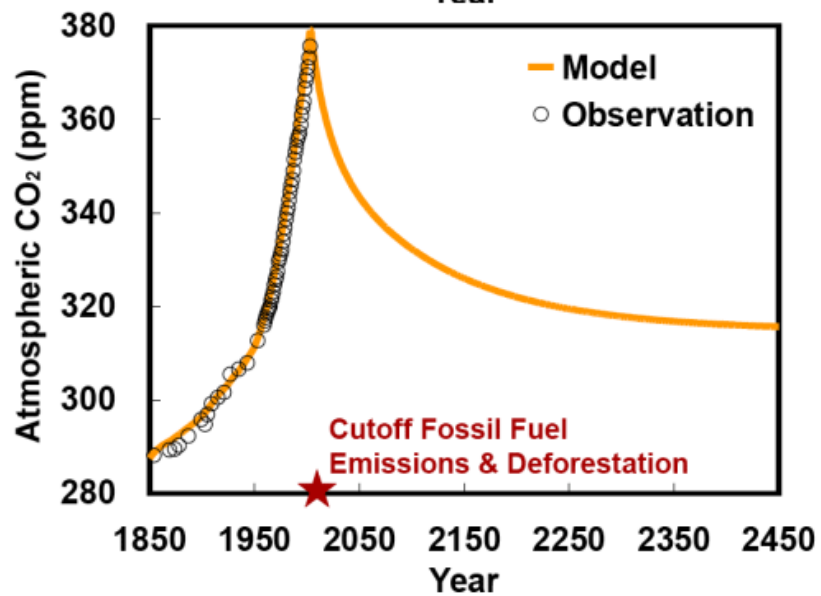
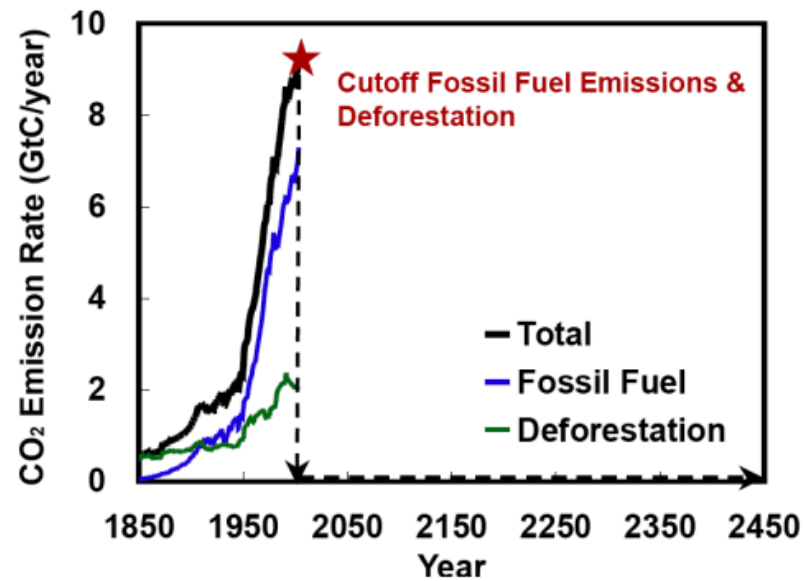
Global Carbon Cycle

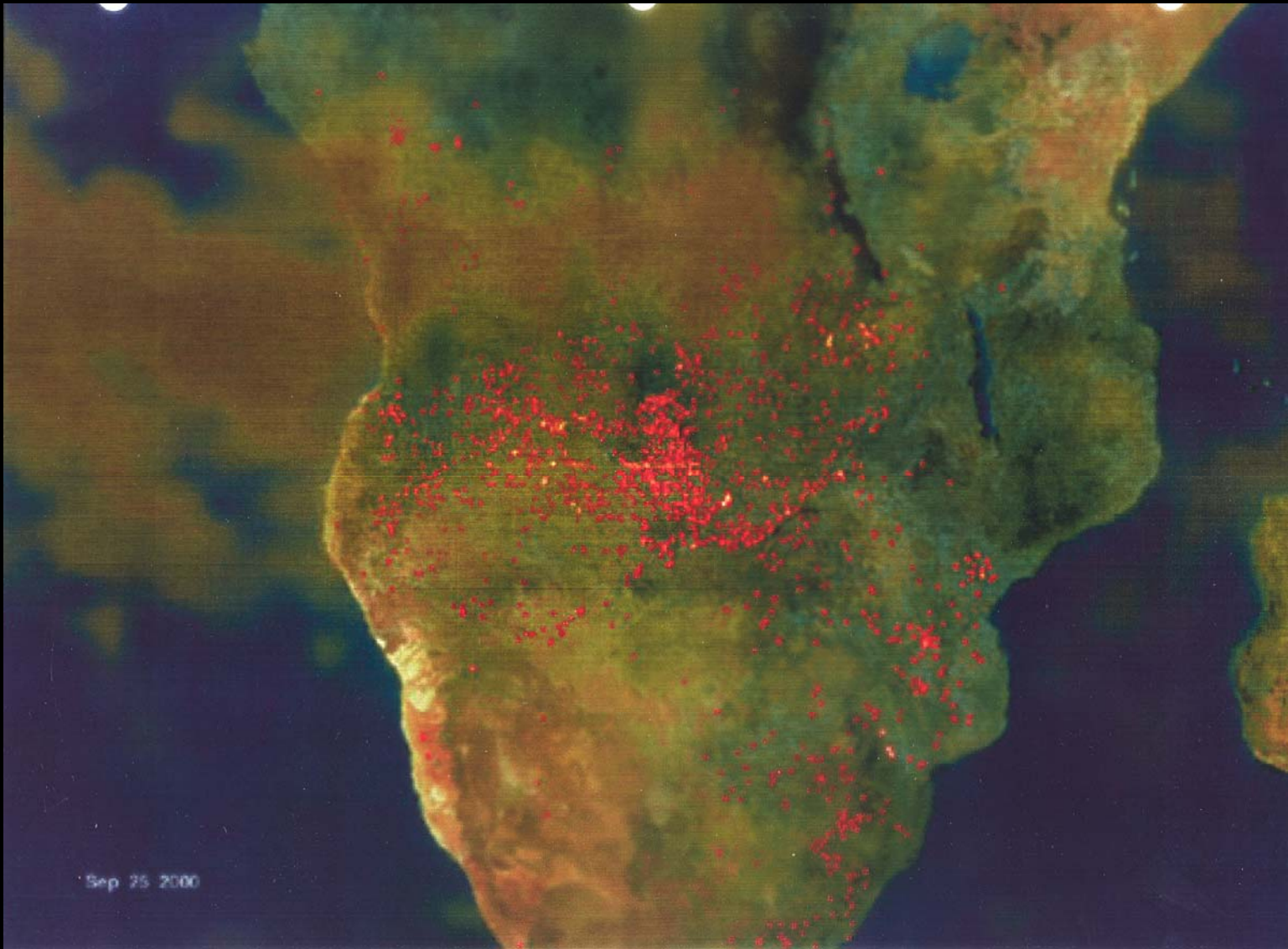


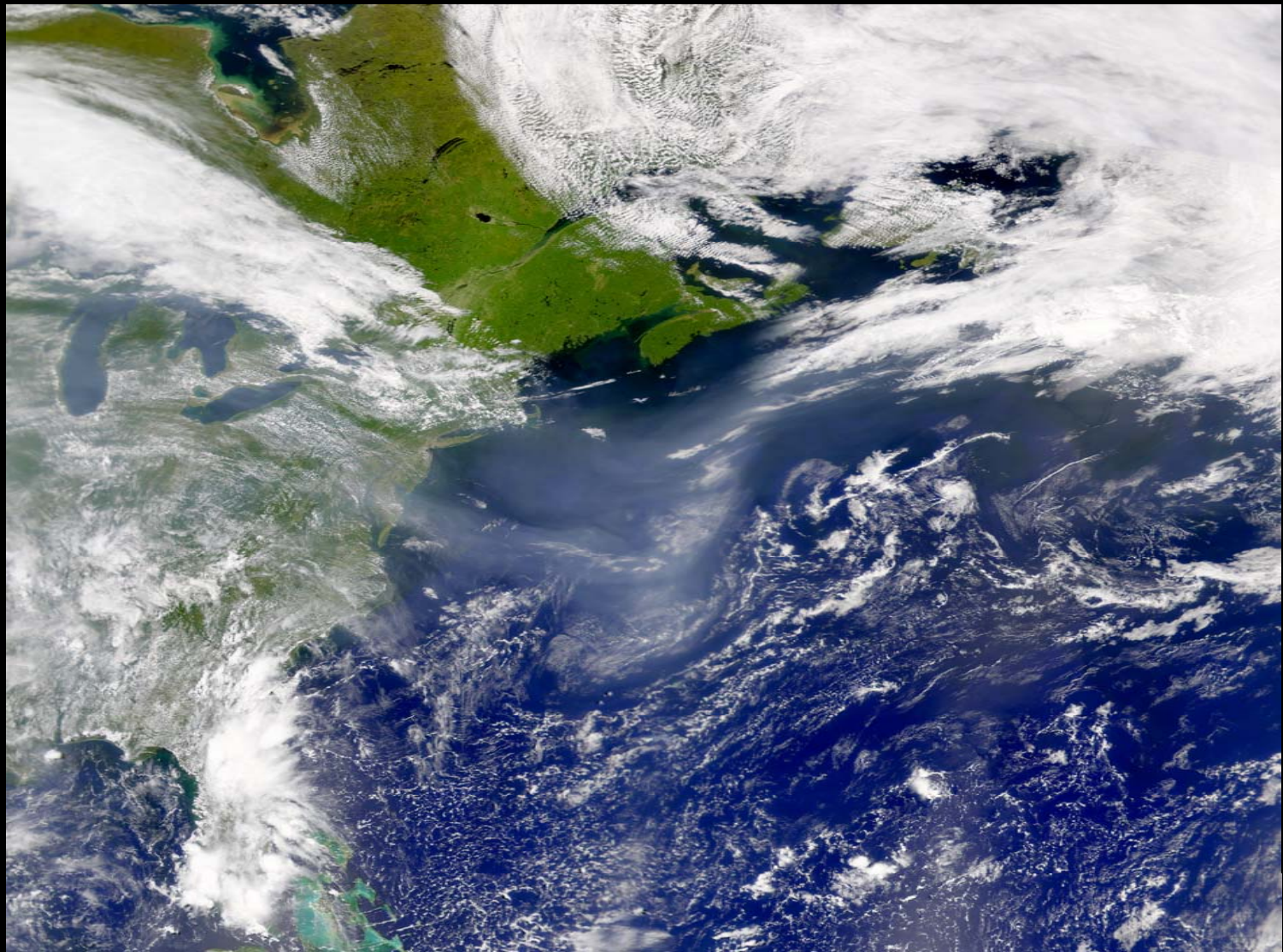


Global fossil fuel CO₂ emissions with division into portions that remain airborne or are soaked up by the ocean and land. *Source: Hansen and Sato, PNAS, 101, 16109, 2004.*



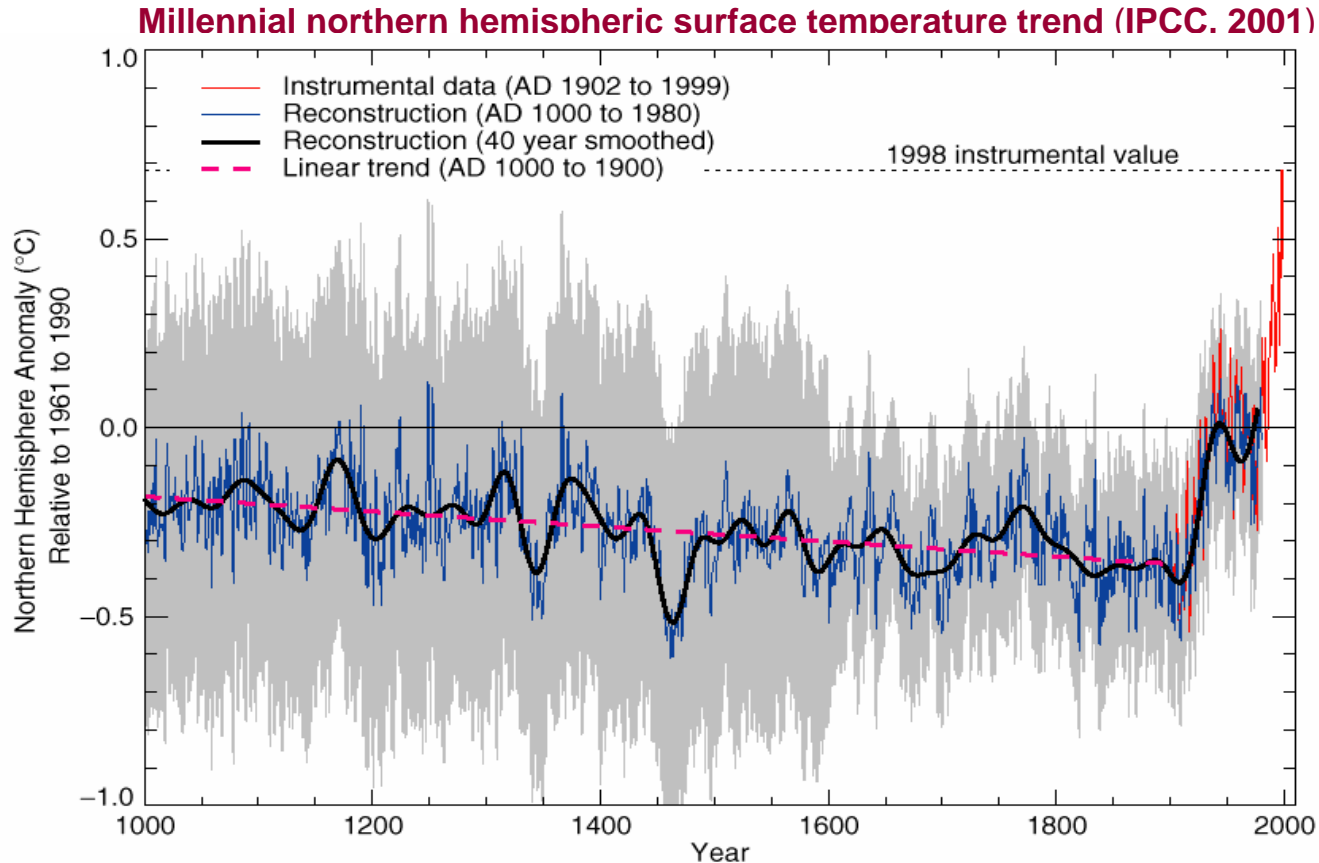








Climate Change Over Past Century

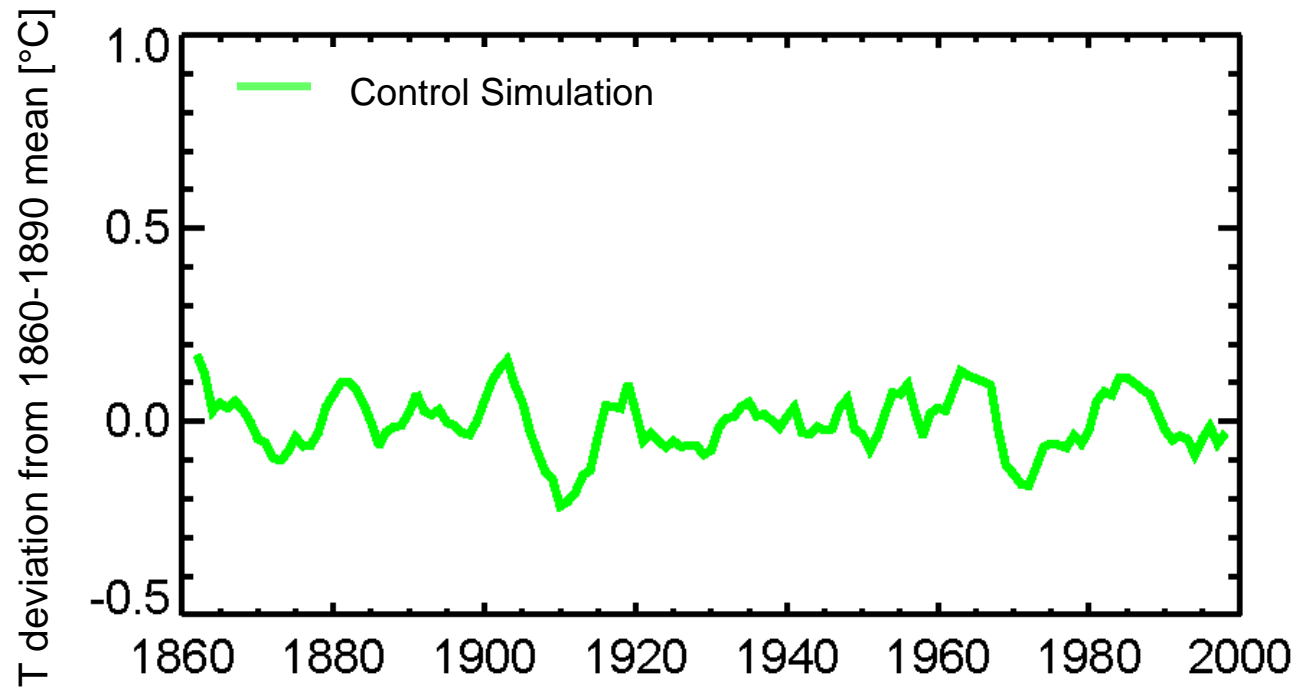


Global mean surface air temperature has increased by 0.6°C in the past 3 decades and 0.8°C in the past century. Slow warming over the century up 1975, followed by rapid warming at $\sim 0.2^{\circ}\text{C}/\text{decade}$.

Control Simulation

Evolution of the global annual mean surface air temperature without anthropogenic perturbations, volcanoes, and solar variability

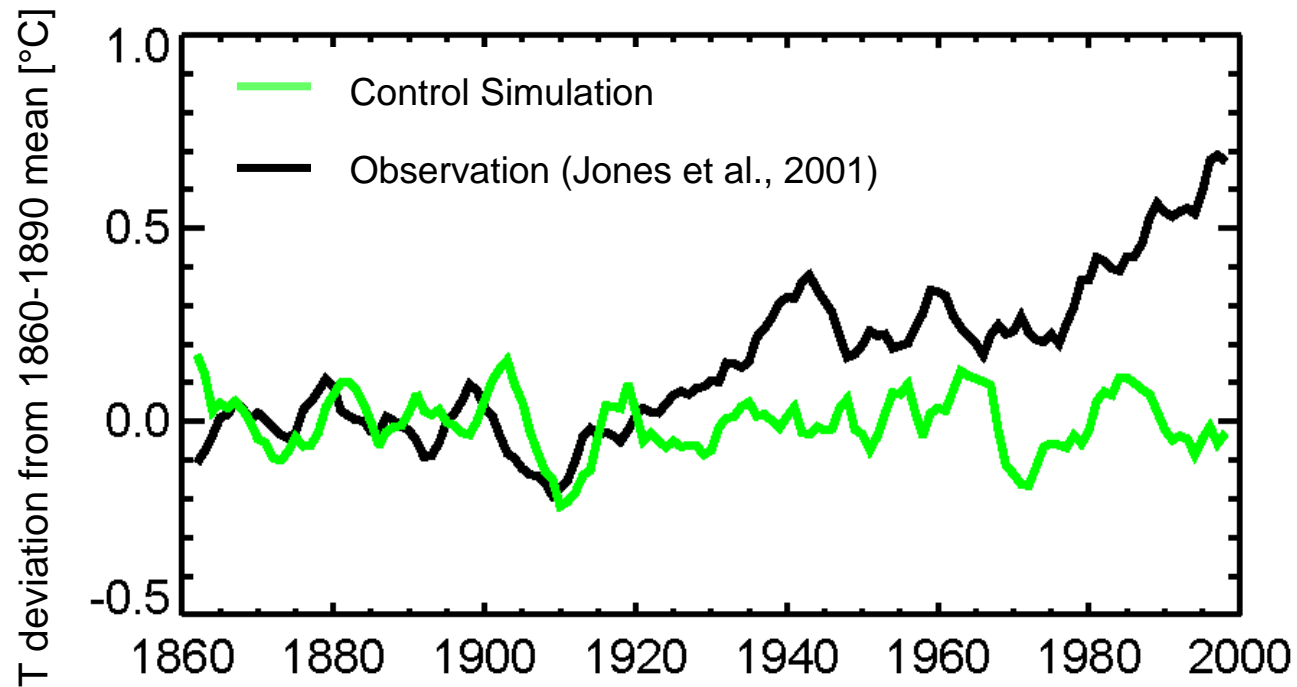
Transient Climate Simulations



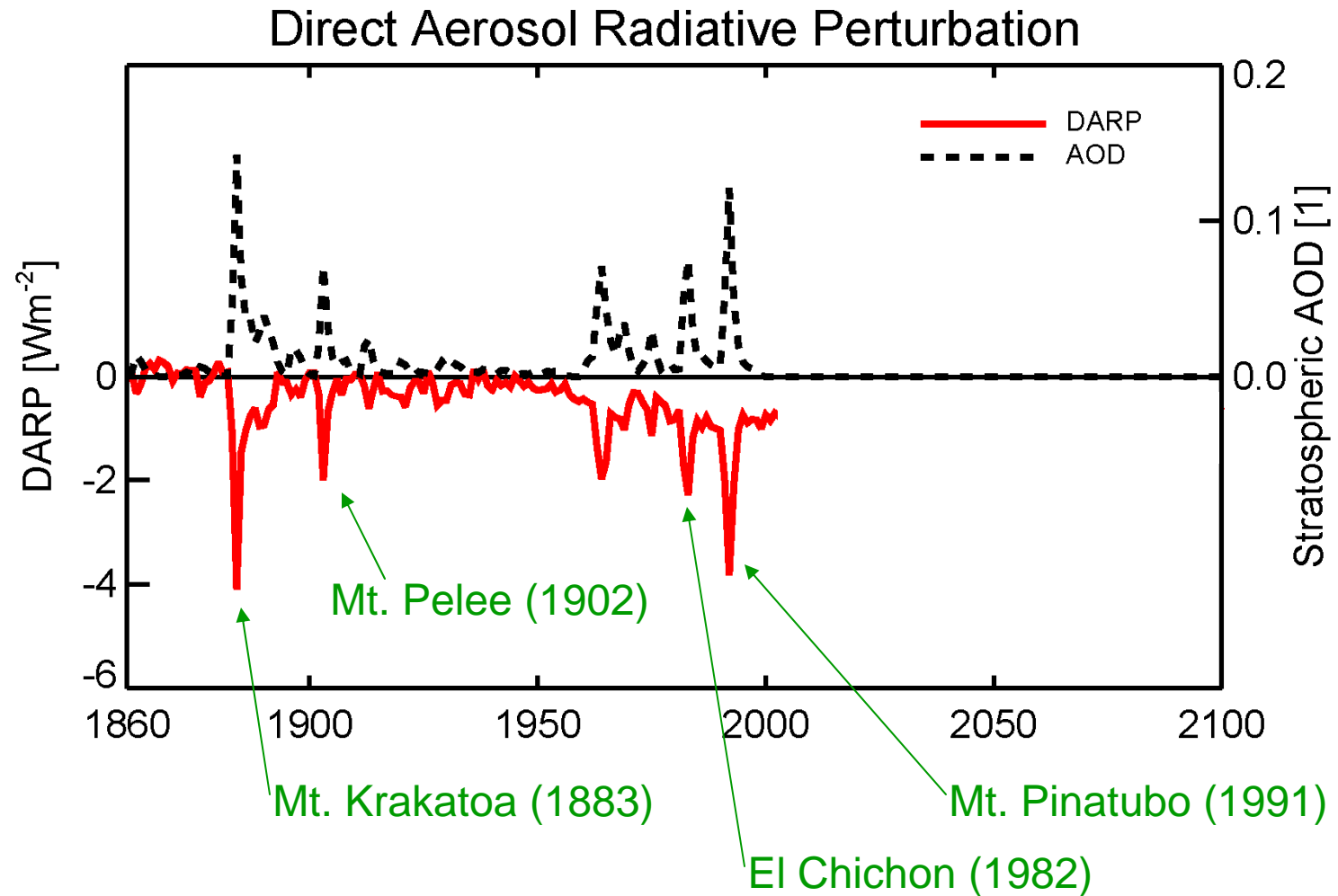
Control Simulation

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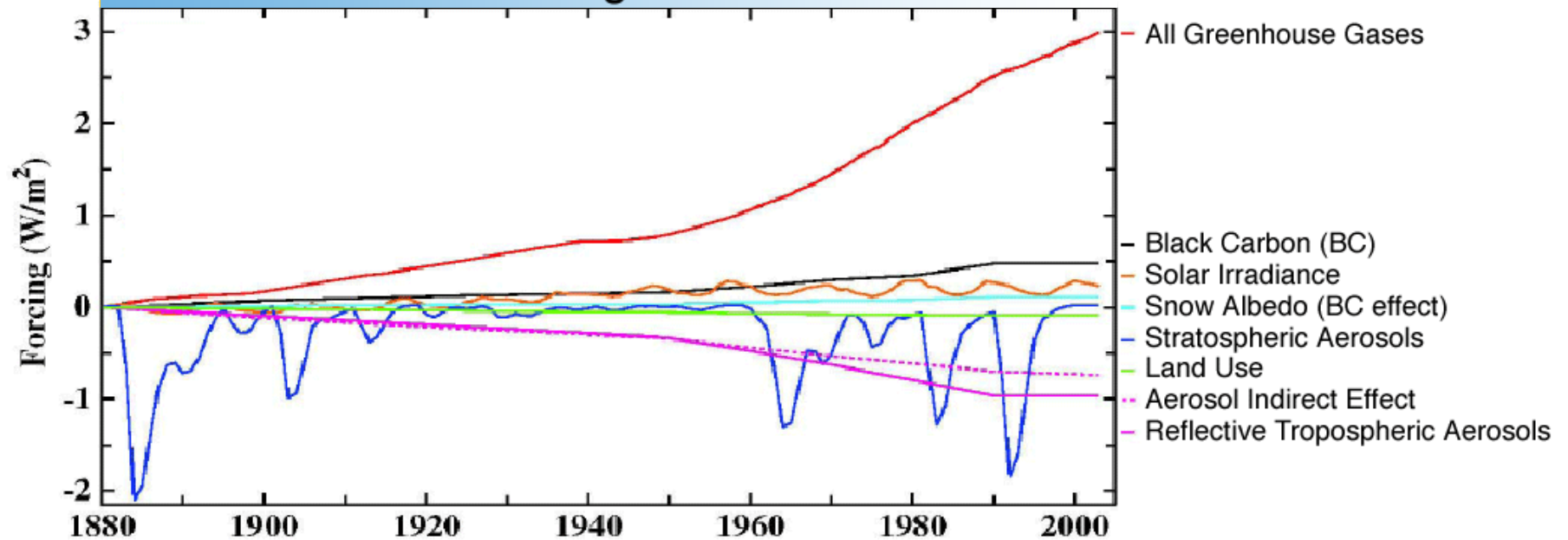
Transient Climate Simulations



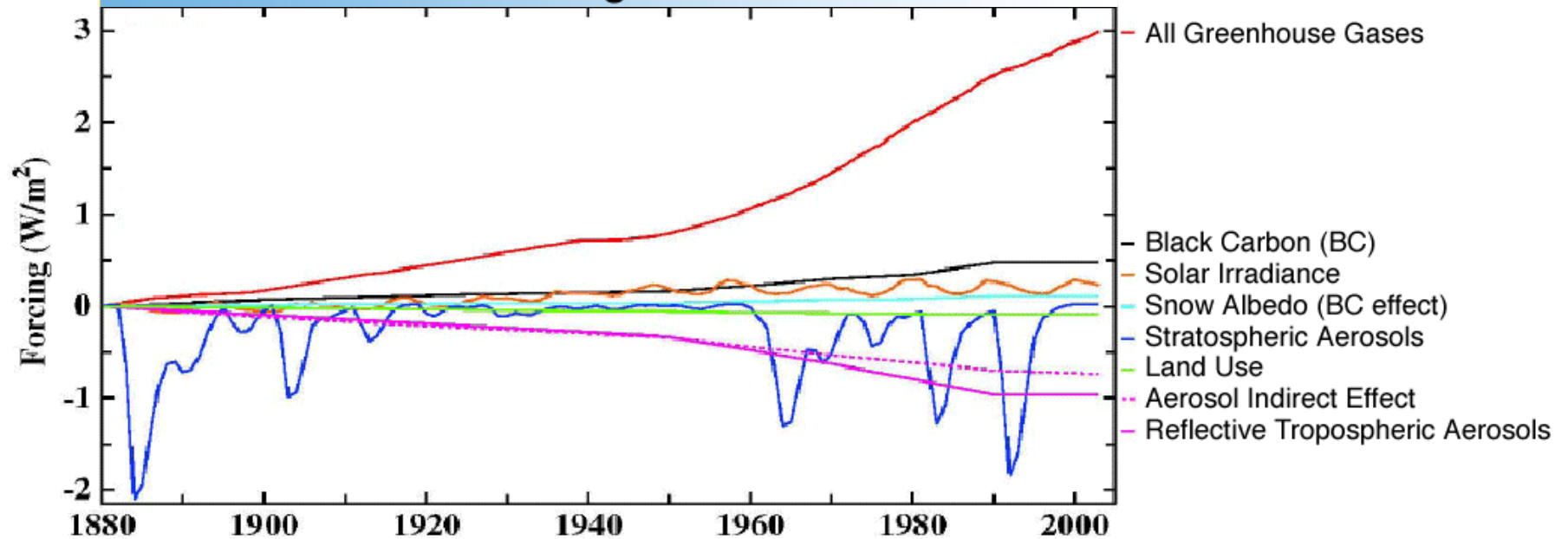
Aerosol Radiative Perturbations



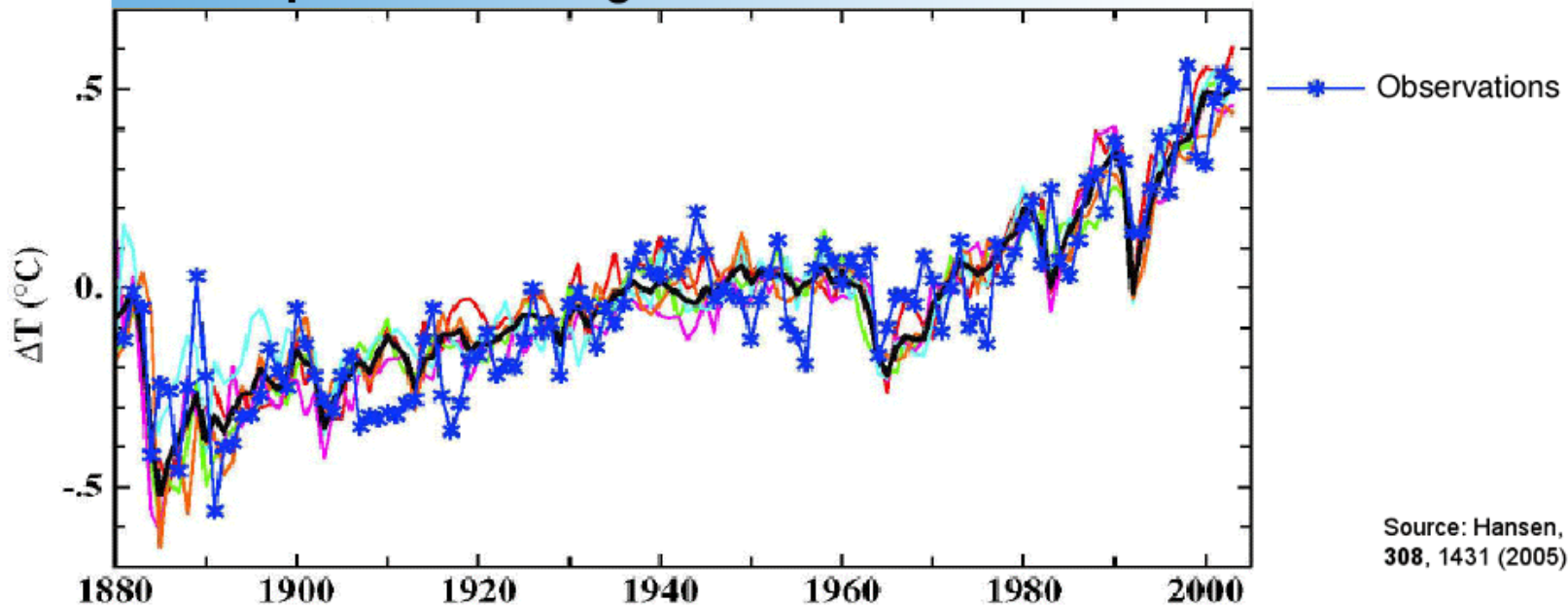
Global Climate Forcings



Global Climate Forcings

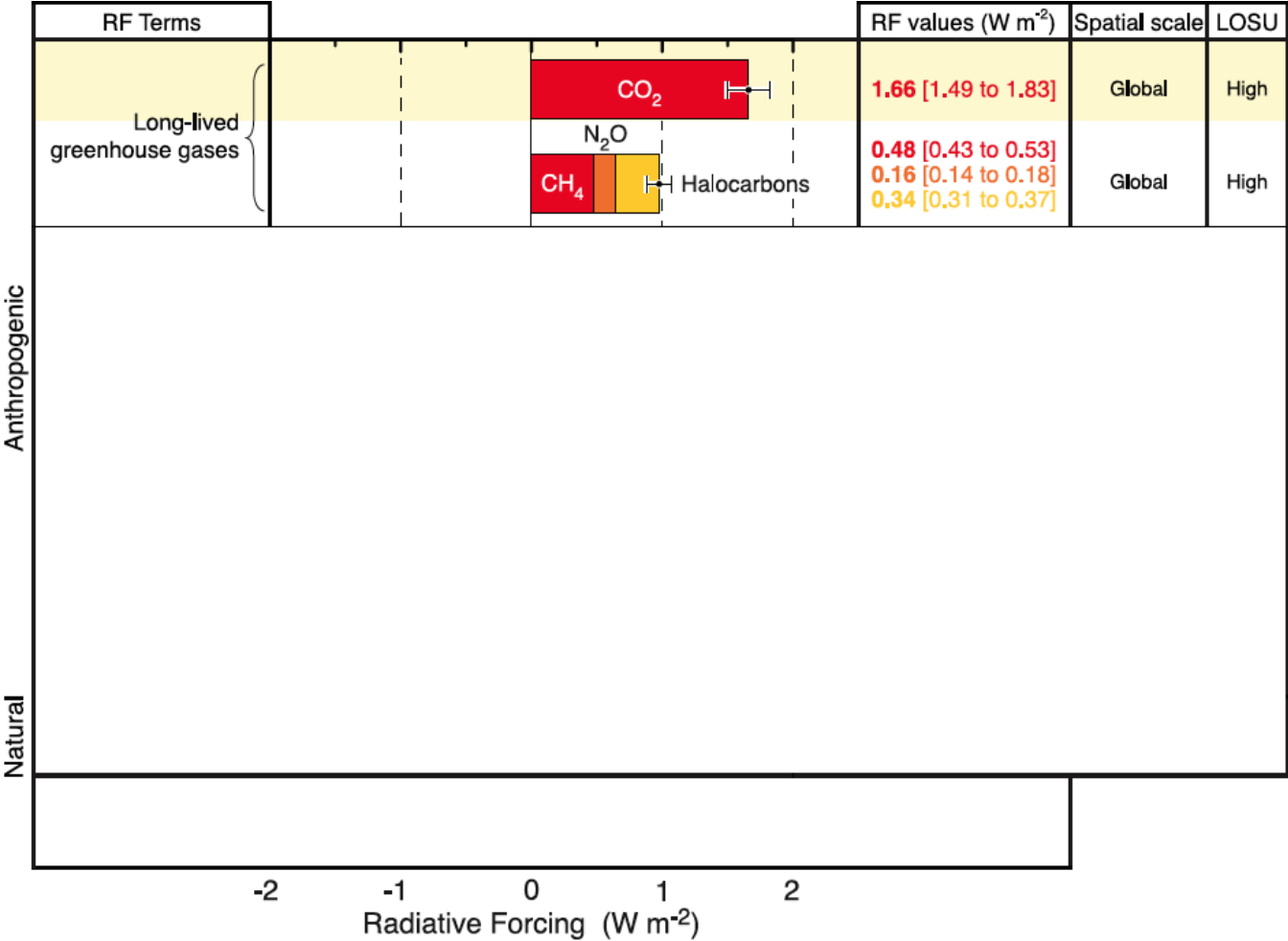


Temperature Change



Source: Hansen, J. et al. *Science*,
308, 1431 (2005)

The Global Mean Radiative Forcing of the Climate System for the Year 2007, relative to 1750



The Global Mean Radiative Forcing of the Climate System for the Year 2007, relative to 1750

